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A Study on Changing of Energy-Saving Performance of GHP Air Conditioning System with Time-Series Variation

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***Abstract*—**This paper deals the energy saving performance of GHP (Gas engine heat pump) air conditioning system has improved with time-series variation. There are two types of air conditioning systems, VRF (Variable refrigerant flow) and central cooling and heating system. VRF is classified as EHP (Electric driven heat pump) and GHP. EHP drives the compressor with electric motor. GHP drives the compressor with the gas engine. The electric consumption of GHP is less than one tenth of EHP does.

In this study, the energy consumption data of GHP installed the junior high schools was collected. An annual and monthly energy consumption per rated thermal output power of each apparatus was calculated, and then their energy efficiency was analyzed. From these data, we investigated improvement of the energy saving of the GHP air conditioning system by the change in the generation.

***Keywords*—**Energy-saving, VRF, GHP, EHP, Air Conditioning System.

I. Introduction

FIG. 1 shows the outline of GHP air conditioning system. GHP system operates by using LNG gas to power a gas engine which drives the heat pump. The main difference between GHP and EHP is whether it uses an electric motor or a gas engine to drive the compressor in the outdoor unit. The outdoor unit is the heart of air conditioning system. In the outdoor part, GHP uses gas, and EHP uses the electricity. Fig. 1 shows the cooling cycle of air conditioning system. After the Great East Japan earthquake, deterioration of the balance of power demand cannot be ignored. Because of the high efficiency, ease of installation and reduction of initial cost, the adoption of GHP has increased rapidly, as in [1].

In this study, the GHP air conditioning systems are set in educational institutions and analyzed according to different manufactured years on energy consumption, as in [3], [5]. Then the rated thermal output produced per unit gas consumption is compared, and the energy consumption is analyzed before and after the renewal of air conditioning system. Based on the analysis, the relevant changes in energy consumption efficiency and answer the question of whether the energy consumption and energy efficiency have been improved is confirmed.

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II. Outline of Analyzed Data

A. Data Collection

196 sets of gas consumption data in elementary and junior high school in Tokyo, Nagoya and Osaka are collected. According to the sets of different manufactured years, their consumption was divided into four groups, which are group COP1.1, group COP 1.3, group COP 1.5 (the above three belongs to type COP) and group APF (Table I). Fig. 2 illustrates a comparison between public and private school gas consumption. Fig. 3 shows the outdoor temperature from April 2009 to March 2010 and the average temperature in Tokyo in last ten years. In this figure, the outdoor temperature has not changed greatly, indicating that there is no difference in energy consumption caused by the outdoor temperature. From the comparison between public and private schools, private schools consume 30% more gas than that of public schools.

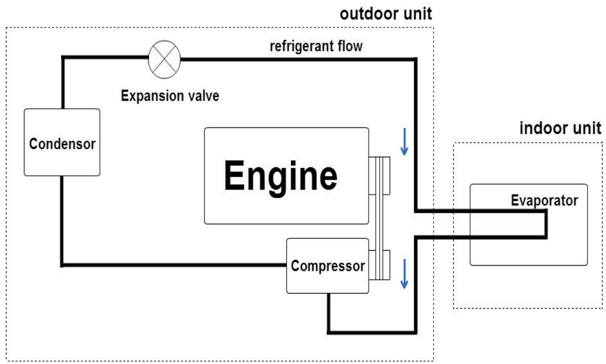

Fig. 1 Outline of GHP system (cooling cycle)

TABLE I
GHP Model Classification

	Model Classification	Tokyo	Osaka	Nagoya	Total
1	COP Type 1（COP about 1.1	50	10	1	61
2	COP Type 2（COP about 1.3	7	0	6	13
3	COP Type 3（COP about 1.5	24	10	6	40
	Total	81	20	13	114
4	APF Type	58	15	9	82
	Total	139	35	22	196

COP (Coefficient of performance) is the ratio of cooling or heating to energy consumption. The COP provides a measure of performance for heat pumps that is analogous to thermal efficiency for power cycles.

APF (Annual performance factor) is the ratio of the total amount of heat the equipment can remove from and add to the indoor air during the cooling and heating seasons.

It takes into account not only power consumption at rated time but also load conditions such as buildings where air conditioners are used and purpose of use, outside air temperature while cooling or heating, and efficiency of the air conditioning system depending on the different capacities of inverter devices, thus making it possible to evaluate energy consumption performance against utilization. APF=f(cooling rated COP, cooling median COP, heating rated COP, heating median COP, heating low-temperature COP, duration of outside air temperature.

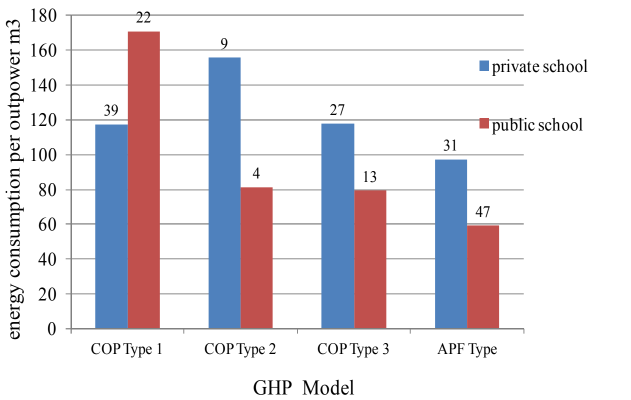

Fig. 2 Energy consumption per rated thermal output power annual

Fig. 2 shows the energy consumption per rated thermal output power annual between public school and private school. The energy consumption of public school is less than that of private school.

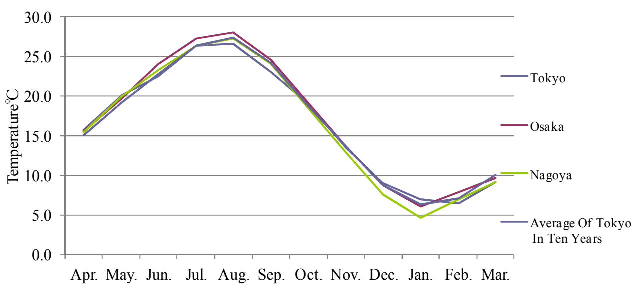

Fig. 3 Temperature of Tokyo, Osaka, Nakoya and the average of Tokyo in ten years

B. Analysis Result

1. Comparison of Energy Consumption per Rated Thermal Output Power

a) Changes of Annual Gas Consumption

Fig. 4 shows the descending trend of gas consumption in different types. As the energy consumption of COP type 1 is 100%, and that of COP type 2 is 97.1%, type 3 is 77.2%, and type 4 is 53.6%. The consumption of the newest type is about half of the oldest one.

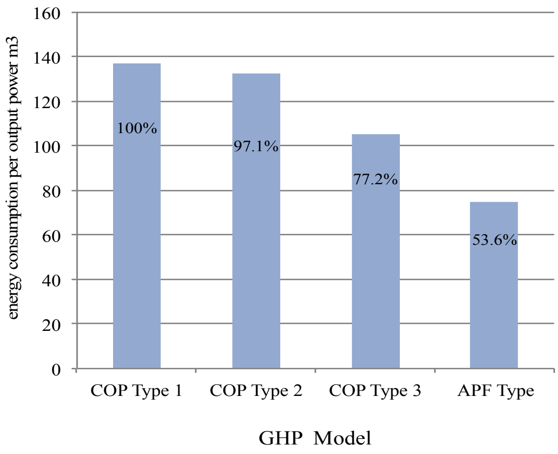

Fig. 4 Annual energy consumption per rated thermal output power

b) Changes of Monthly Gas Consumption

Fig. 5 shows the energy consumption per rated thermal output power each month. From the figure, with update of the manufactures, gas consumption reduces greatly. And the reduction of energy consumption in summer is more than that in winter.

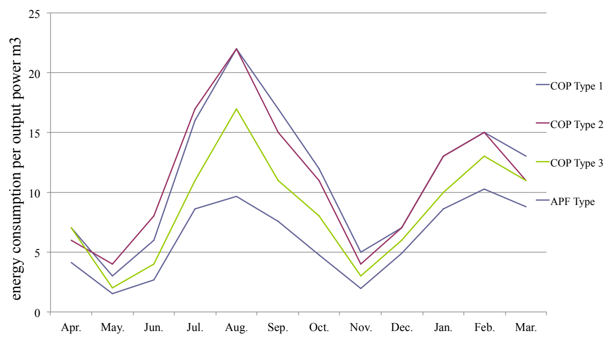

Fig. 5 Monthly energy consumption per rated thermal output power

2. The analysis of the Renewed Manufacture

About the comparison of annual and monthly gas consumption above, the length of the machine running time and the air conditioning area and so on was not taken into account. Now the gas consumption data before and after the renewal of air conditioning system at the same school are calculated and compared.

Table II shows the specification of renewed system. The building for the investigation is a junior high school in Tokyo. The school type, the floor space, the number of students, the operating time and so on. It also shows the condition of GHP renewed before and after.

Fig. 6 shows the outdoor temperature in Tokyo area during the period of data collection. The outdoor temperature has not changed greatly, indicating that there is no special year during data collection

TABLE II
SPECIFICATION OF RENEWED SYSTEM

Purpose			Classroom	School Office
Data of Building		Location	Tokyo	Tokyo
		Republic/Private	Republic	Republic
		School Type	Junior high school	Junior high school
		Floor Space	4800m2	4800m2
		Floor Space of Air Conditioni	960m2	330m2
		The Number of Students	355	355
		Operating Time	983H	2661H
GHP	Renewed Before	Output Power	40HP	15.5HP
		Installatin Date	September 1, 1993	June 1, 1995
		Model of Outdoor Unit	COP type 1 8	COP type 1 1
				COP type 1 1
				COP type 1 1
	Renewed	Output Power	40HP	16HP
		Installatin Date	October 1, 2008	October 1, 2008
		Model of Outdoor Unit	APF type 2	APF type 1

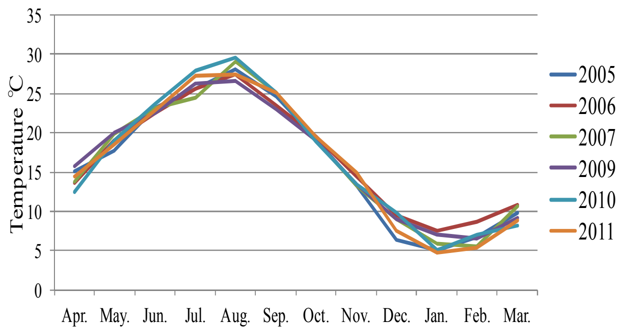

Fig. 6 Comparison of outside temperature

Figs. 7 and 8 show the comparison of the energy consumption that the system renewed before and after. The energy consumption per unit of the classroom reduced about 45% compared to it renewed before.

C. Data Analysis by Utilization of DECC

1. DECC Data

The DECC (Database for Energy Consumption of Commercial buildings) is a Japanese database about the energy consumption of the commercial building. The data was collected by cooperation of industrial, administrative and academic sectors, and 50 or more universities and research institution participate in this working.

DECC is the first national database related to building energy and water consumption. The purpose of this database is reduction of the greenhouse gas emissions from a building and it was produced by cooperation of the 'Ministry of Land, Infrastructure and Transport'. DECC is divided into Basic Database and Detailed Database, due to differences of the data structure. In this paper, the energy consumption data of the elementary school, junior high school and high school in Tokyo was used, as in [2], [4].

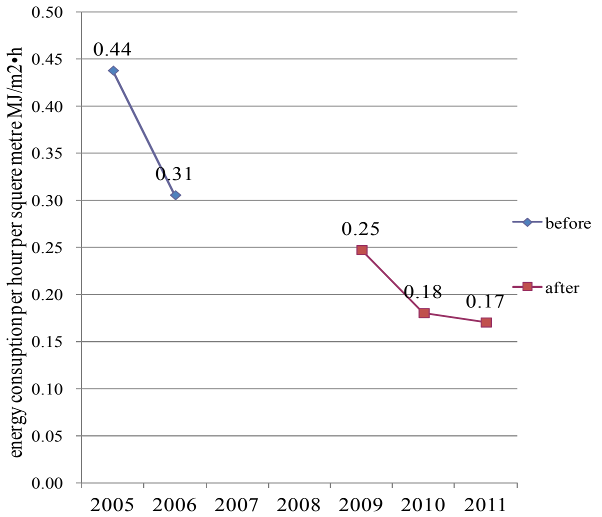

Fig. 7 Comparison of the energy consumption that the system renewed before and after (classroom)

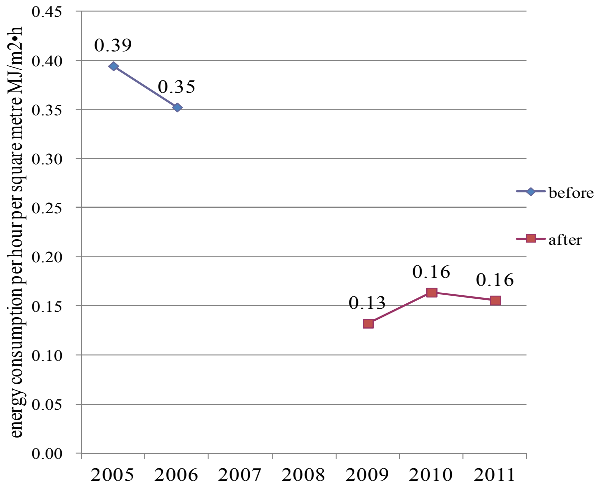

Fig. 8 Comparison of the energy consumption that the system renewed before and after (office)

Fig. 9 shows the monthly energy consumption in Tokyo public high schools calculated by DECC level 1 data (DECC is divided into three kinds, Basic database Level 1,Standard database Level 2 and Detailed database Level 3 by the difference in the field structure of a database). The red line in the figure shows the base energy level without the consumption for air conditioning system, and the part of above the red line is the air conditioning energy consumption. Fig. 10 shows the energy consumption of air conditioning system in the public junior high school (the renewed manufacture). Comparing with the part of above the red line in Fig. 9 (air conditioning energy consumption), the pattern in the Fig. 10 is consistent with that of DECC.

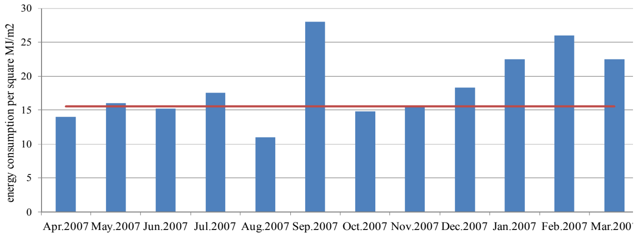

Fig. 9 Energy consumption per unit of the whole manufacture (DECC)

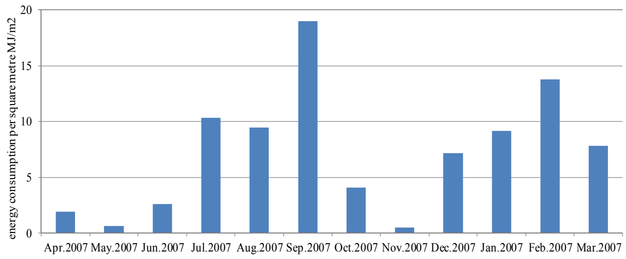

Fig. 10 Energy consumption per unit of the air conditioning system (renewed manufacture)

2. Heat Load Calculation Program

The HASP/ACLD/8501 (hereinafter collectively referred as 'HASP') program of the air conditioning load to calculate the heat load is used. Figs. 11-13 show the outline of the architecture.

a) Outline of the Architecture

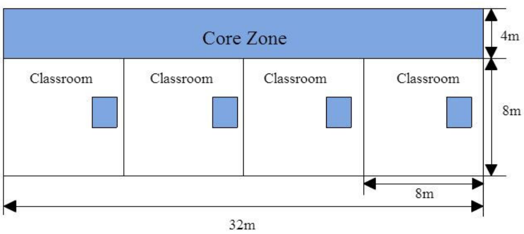

Fig. 11 Plane figure of the school

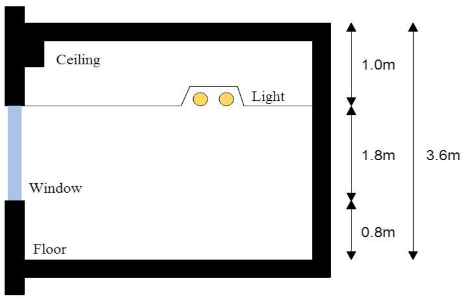

Fig. 12 Cross section of floor

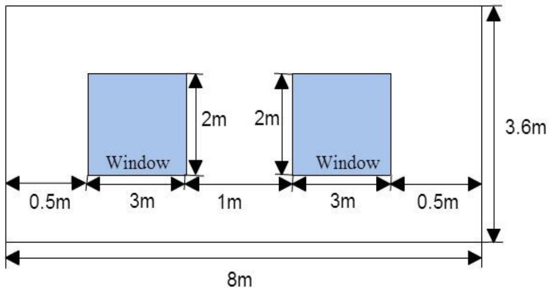

Fig. 13 Exterior wall

TABLE III
SPECIFICATION OF ARCHITECTURE

Use		School
Region		Tokyo
Number of Storey		2nd Floor
Total Area		768m2
Outer Wall		Rigid Urethane Spray 25mm
		Ordinary Concrete 150mm
		Mortar 20mm Tile 8mm
Floor(Ceiling)		Ordinary Concrete 150mm Unsealed Air Layer
		Gypsum Plate 9mm
		Rock Wool Acoustic Board 2mm
Furniture		15KJ/m2K(sensible heat) 15KJ/m2K(latent heat)
Internal Heat	Light	20W/m2
	Person	0.2person/m2
	Machines	15W/m2
Air Conditoning conditions	Summer	Temperature26℃ Humidity50%
	Winter	Temperature22℃ Humidity40%
	Summer	8:30~16:00
Shutdown Days		Weekends&Holidays
Air Introduction		25m2/(h ·person)

b) Climate Condition (Tokyo)

The climate conditions are obtained from AMeDAS (Automated meteorological data acquisition system) weather data that is distributed by Japan Meteorological Agency. In this paper, the average of 30 years (1981~2010) was used. Wet bulb temperature and absolute humidity are calculated by the characteristic equation of moist air. Wet bulb temperature is used for calculating condenser water inlet temperature in cooling tower. Fig. 14 shows the climate condition.

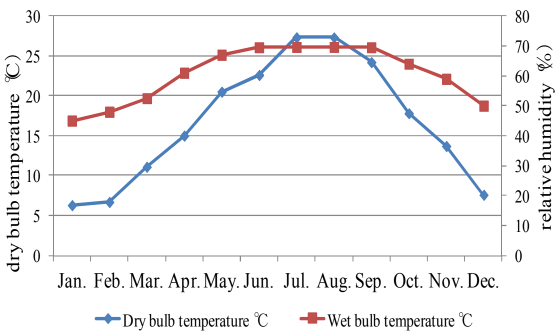

Fig. 14 Climate condition

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c) Calculation Results

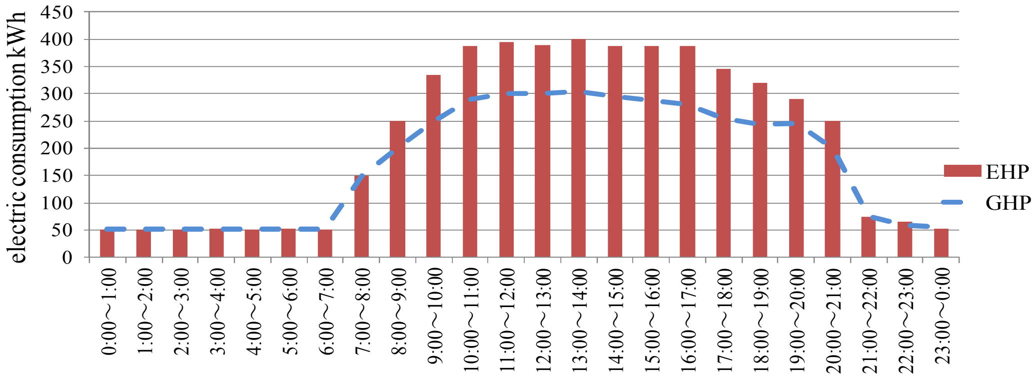

Fig. 15 Verification of the energy-saving performance (total)

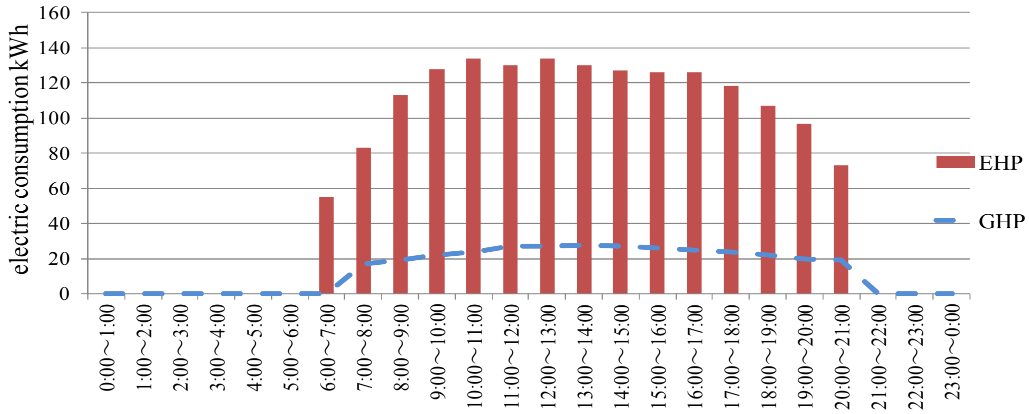

Fig. 16 Verification of the energy-saving performance (air conditioning system)

TABLE IV
SPECIFICATION OF SIMULATION

Heat Source Equipment				EHP	GHP
Region				Tokyo	
Outdoor Unit	Number			4	1
	Air Conditioners Lower		%	25	25
	Cooling	Rated Output	kW	12.5	56
		Rated Input	kW	4.22	1.1
	Heating	Rated Output	kW	14	63
		Rated Input	kW	3.78	1.02
		Low	kW	13.3	63
	Heating and			3.33	1.4
Indoor Unit	Number			1	1
	Maximum Air Volume		m3/h	1860	1680
	Blower Output		kW	0.15	0.13

III. SUMMARY

The energy consumption of the GHP air conditioning system which installed in the educational institutions is analyzed according different manufactured years. Then the improvement of energy efficiency (energy-saving performance) is clarified in this paper. By using the LCEM tools and DECC database, the performance of electric saving was investigated.

The conclusions of this study are following,

1. From the changes of GHP air conditioning system with time-series variation, the energy consumption decreased about 40% in the 20 years.
2. About the renewed air conditioning system, the operating time and the air conditioning floor space was taken into account, and we found that the reduction proportion of energy consumption is almost the same with the result of the 196 sets data.
3. From the comparison of energy consumption between public and private schools, there is about 30% difference, which is consistent with the results of DECC data.
4. The difference between COP type/APF type and output characteristics of GHP is shown in the energy consumption.
5. About the energy-saving effect, it could save about 50% electric power during summer.
6. This study can be used as guideline for energy consumption prediction when the new educational institutions are constructed or the existing institutions are renovated

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